

The Light Naphtha Surplus and the Potential Impact of Tier 3 Sulfur

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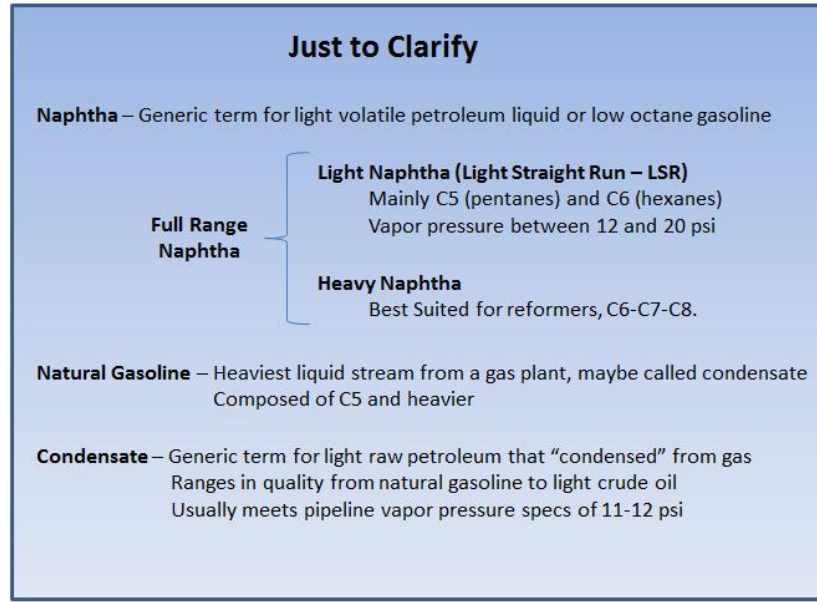


HISTORY OF LIGHT NAPHTHA

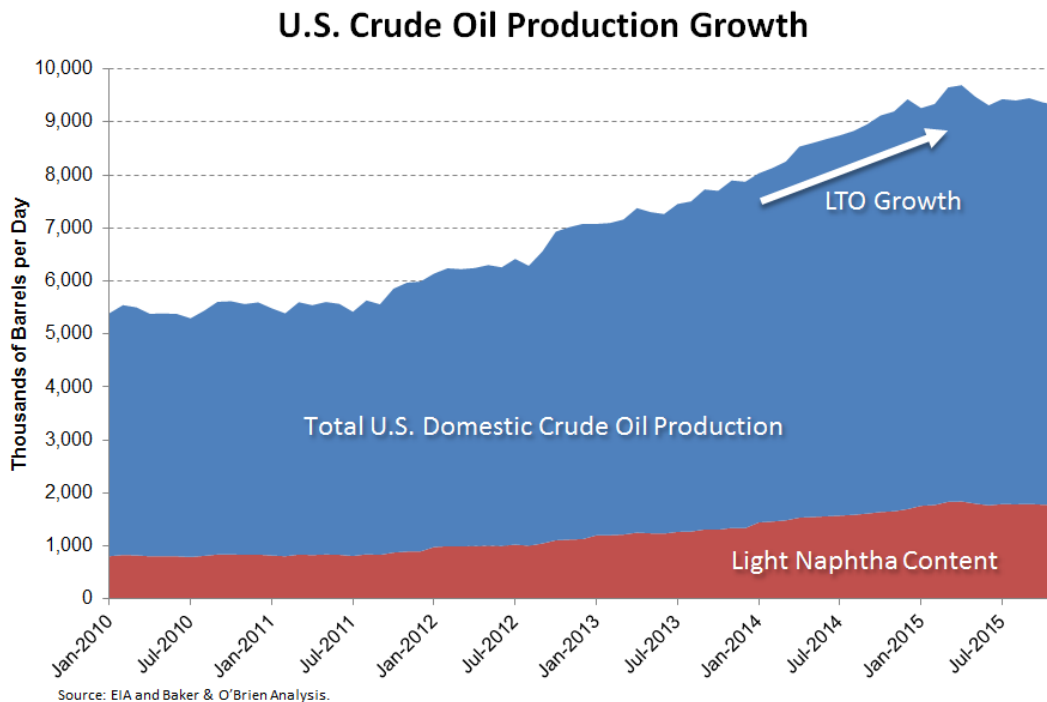
A hundred or so years ago, the best-selling automobile was the Model T Ford and the retail price of gasoline averaged 13 cents per gallon. The main source of motor gasoline was untreated full range naphtha recovered from crude oil through simple distillation. Another source was natural gasoline collected from condensed liquids at natural gas wells (“drip” gasoline). These were the only sources of motor gasoline for decades. In these early years, sulfur content or octane quality was not important as long as the product was clear, free of water, and not dangerously volatile.

As more vehicles took to the road, and vehicle performance improved, important changes in refining were needed, both to increase gasoline yield and provide the octane quality demanded by modern engines. Later, reduction in pollution from motor vehicles became an equally important factor affecting refiners. In contrast to the days when untreated naphtha or natural gasoline was the predominant fuel components, they currently comprise less than 15% of the total U.S. gasoline pool of almost 9.5 million barrels per day (B/D). Gasoline specifications, such as octane, vapor pressure, and distillation temperature limits require the correctly proportioned use of refinery components, such as catalytically cracked gasoline, alkylate, high octane reformate, and isomerate. Most refineries blend untreated light naphtha—also referred to as Light Straight Run (LSR)—directly into gasoline, while heavy naphtha is processed in a reforming unit to increase its octane.

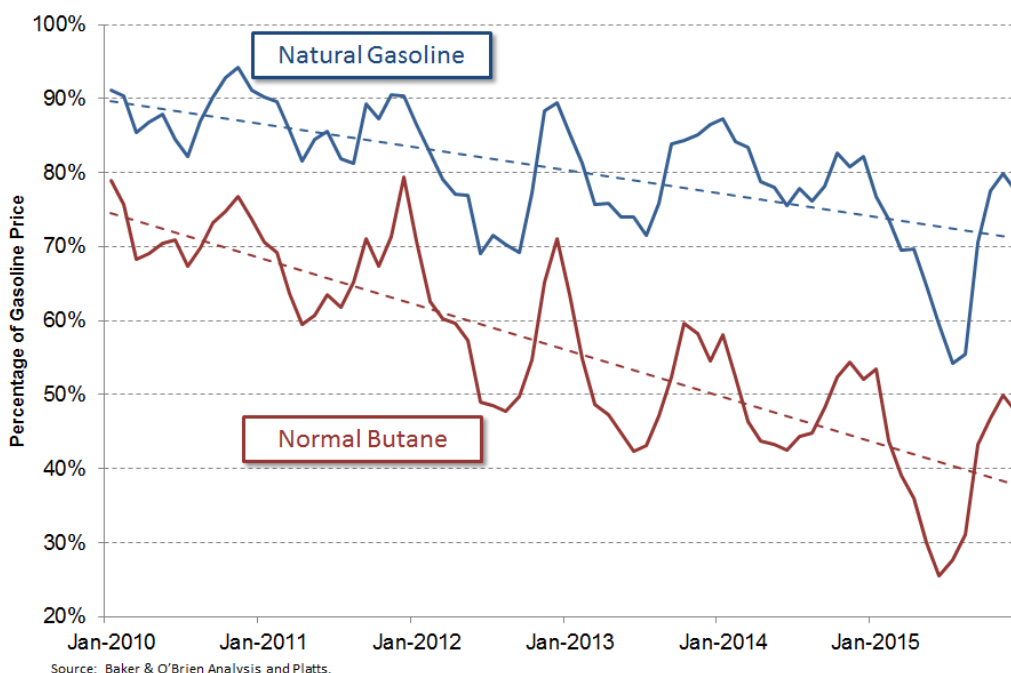
Starting in 2017, the United States (U.S.) Environmental Protection Agency (EPA) Tier 3 rule will set new vehicle emissions standards and lower the sulfur content of gasoline from 30 parts per million (ppm) to 10 ppm. This will present new octane and sulfur challenges to many refineries by making it more difficult to incorporate increasingly available volumes of low octane, high vapor pressure light naphtha in the gasoline pool.



With the production surge of “Light Tight Oil” (LTO) in the U.S., as illustrated below, more light naphtha and natural gasoline has become available for blending into motor gasoline. U.S. refineries and gasoline blenders have been challenged to find ways to blend these volumes into finished gasoline. This is creating a potentially large surplus of these low octane, high vapor pressure components and the need for either new refinery investments or alternative market outlets.



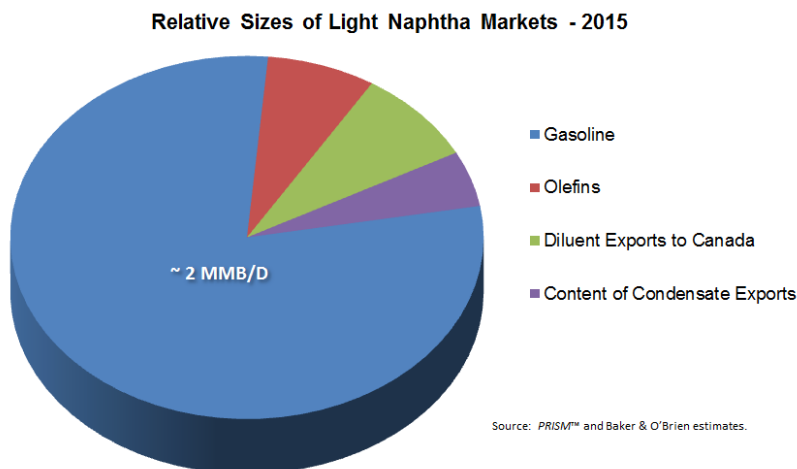
Most U.S. refineries are not designed to process 100% LTO crude into on-road fuels, and often are forced to sell some light intermediate components, such as butane and light naphtha. Surplus amounts of light gasoline blending components have resulted in significant price discounts relative to gasoline, as shown in figure below. Light naphtha values are represented by published prices of natural gasoline due to similar qualities and uses. Because motor gasoline is the primary outlet for butane and light naphtha, prices are frequently quoted as a percentage of wholesale gasoline prices. The steady decline in butane and natural gasoline prices to record lows is a direct result of the increasing surplus of these light materials as refinery blending components.



OTHER OUTLETS FOR LIGHT NAPHTHA

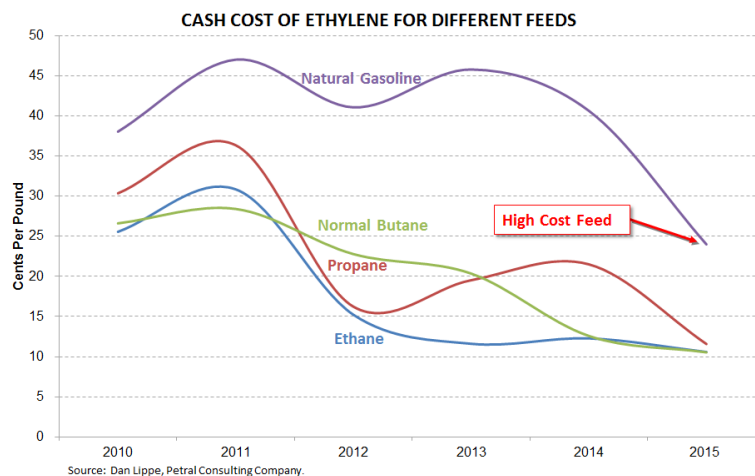
In 2015, the total volume of light naphtha (and natural gasoline) produced in the U.S. was about 2 million B/D. As shown in the pie chart below, motor gasoline has been, by far, the largest outlet for light naphtha. Other markets include: (a) diluent for heavy crude transportation, especially for Canadian produced bitumen; (b) petrochemical feedstock; and (c) exports to areas where octane, vapor pressure, and environmental requirements are less restrictive. Significant volumes of light naphtha have yet to be exported overseas as a single product, although light naphtha has comprised a large proportion of the light condensates that were exported from the U.S. in 2015. However, some of this condensate will be fractionated at new condensate splitters that have recently started up or plan to start up in the next two years, thus releasing more light naphtha onto the world market. Although domestic light crude oil

and condensate production is expected to decline in the near future due to currently low prices, the supply of light naphtha still has the potential to continue to significantly exceed overall demand—especially if the demand for Canadian diluent decreases as expected.



PETROCHEMICAL FEEDSTOCK FOR OLEFINS PRODUCTION

Although motor gasoline is the highest and best use for light naphtha, it can also serve as a petrochemical feedstock for olefins production. In this application, light naphtha (or natural gasoline) competes with lighter, lower cost natural gas liquids, such as ethane, propane, or butane. For this reason, when used in petrochemical production, light naphtha takes on a considerable price discount compared to its gasoline value. However, as shown below, in recent years, light naphtha (natural gasoline) has still been a higher cost petrochemical feedstock in the U.S, and the least economically attractive if ethylene is the desired end product. Under these circumstances, especially with ample available supplies of natural gas liquids, it is not expected that the U.S. petrochemical market will represent a significant outlet, unless the light naphtha price declines even further from today's low levels.



DILUENT FOR HEAVY CRUDE TRANSPORTATION

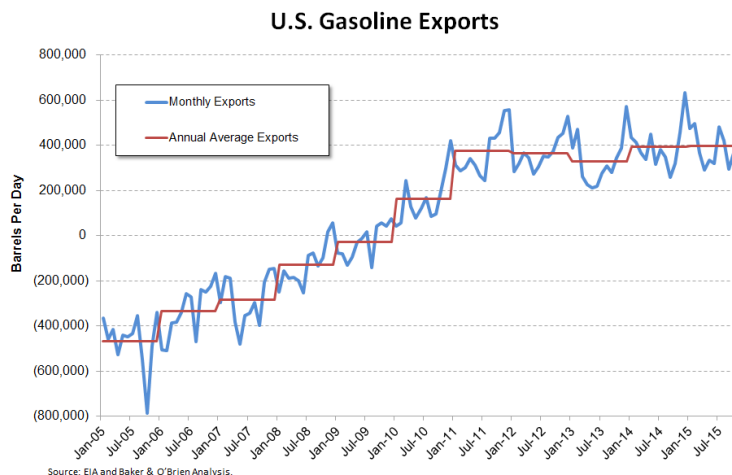
Light naphtha is also used as a diluent for heavy Canadian crude transportation. In recent years, diluent demand has increased considerably to match the heavy crude production in Alberta. To dilute heavy bitumen crude, as much as 30% by volume is required for shipments to U.S. refineries. Both pipelines and rail cars transport diluent to Canada from as far as south Texas only to be recycled as diluted bitumen back into the U.S. This diluted bitumen (or “dil-bit”) is processed in a refinery distillation unit, which frees up the light naphtha to be used again.

Recent projections of diluent demand for import into Canada were expected to reach as high as 500,000 B/D by 2020. However, low oil prices will likely stymie the growth of bitumen production along with diluent demand.

The quality of diluent is not as important as the price. Because bitumen blenders are essentially paying to transport diluent twice, they typically choose the lowest cost cutter stock. For diluent purposes, light naphtha competes with other low priced light hydrocarbons, such as butane, pentane, and natural gasoline.

GASOLINE EXPORTS – LEVELING OFF

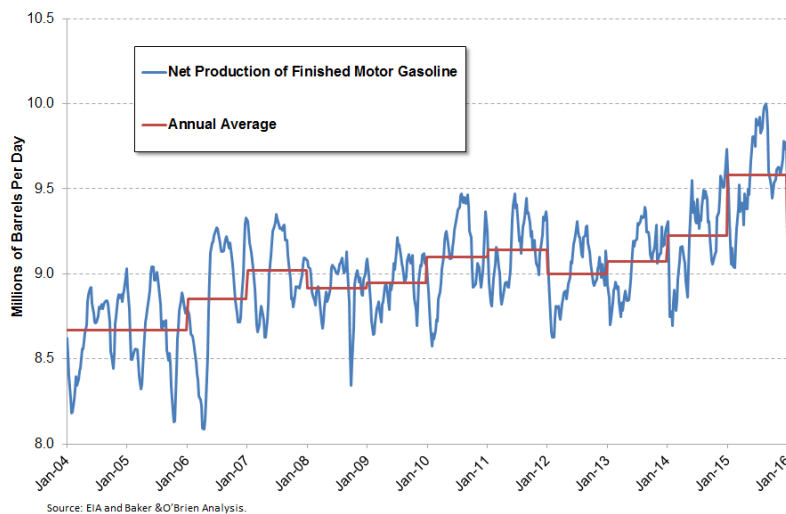
Some U.S. refiners have responded to new environmental regulations (especially the Tier 2 sulfur regulations) and the increase in light crude oil production by exporting lower octane, higher sulfur gasoline than permitted in the U.S. Record amounts of gasoline exports have allowed the U.S. to transition from being a net importer to becoming a net exporter of gasoline and components. However, as shown below, export volumes have been leveling off as several refiners and blenders compete for the same export markets. The competition for these markets may intensify as the light naphtha surplus increases and Tier 3 sulfur regulations take effect. Thus, exports as a potential outlet for light naphtha may be increasingly limited.



MOTOR GASOLINE BLENDING – MEETING THE CHALLENGES

Because the alternative outlets for light naphtha are limited, unless prices drop substantially, refiners are increasingly seeking new ways to incorporate these materials into the gasoline pool. As previously stated, light naphtha has been a consistent blendstock for motor gasoline in percentages as high as 100% (many years ago) to 15% or less (on average). Due to its low octane value, light naphtha requires octane boosters or mixing with higher octane components. Tetraethyl lead and MTBE (methyl tertiary-butyl ether) are examples of gasoline additives that were previously used, but have been phased out of gasoline sold in the U.S. Other blending components, such as alkylate and reformate, can be used to raise octane in order to meet on-road fuel specifications, but they are limited in volume and are costly from both an investment and operating standpoint.

Due to recent high volumes and resulting low prices for light naphtha, refiners have responded by producing more gasoline from each barrel of crude oil processed. Production of finished gasoline hit record levels in 2015, as shown below.



OCTANE COSTS

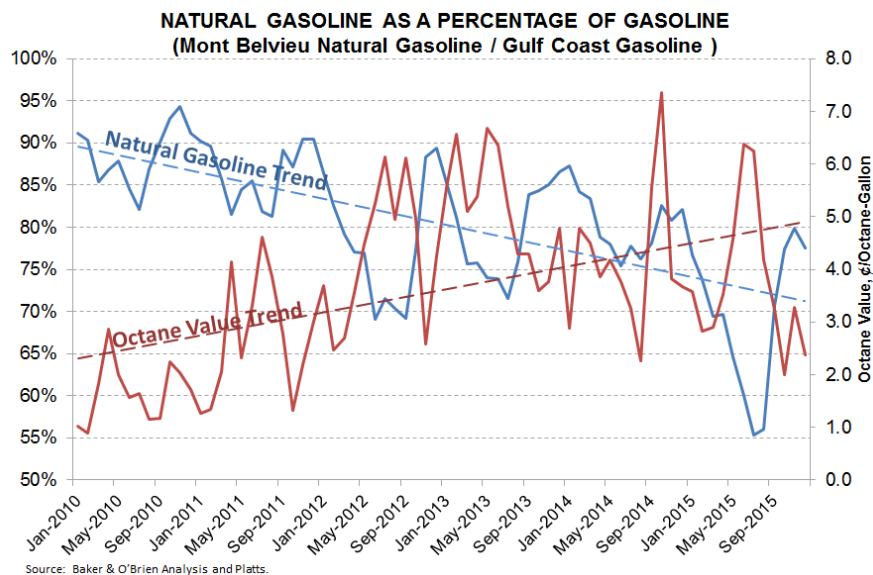
Light naphtha has an octane number of about 70, which is significantly less than the regular motor gasoline octane requirement at 87. To absorb the low octane of light naphtha in a refinery's gasoline pool, high octane components are produced or bought and, thus, incur higher blending costs. The cost of this correction lowers the true value of light naphtha as a blend component.

In some refineries, light naphtha octane is upgraded by use of an isomerization (isom) unit. Using catalyst, heat, and hydrogen, an isom unit changes the chemical structure of light naphtha and raises the octane by approximately 10 numbers. Unfortunately, the octane

increase comes with an increase in vapor pressure, which restricts the use of low cost butane as a blendstock, especially in the summer. Isom units also add manufacturing costs.

Almost all refineries that manufacture gasoline incorporate reforming units that raise the octane of heavy naphtha from about 50-60 to 95 or higher. This is one of the main octane contributors in the refinery. However, reforming is costly due to expensive catalyst and the high temperatures (>900 degrees Fahrenheit [°F]) required. The liquid product from reformers ("reformate") also shrinks slightly in volume as hydrogen gas is released during the reforming process. This shrinkage adds cost due to the loss in product volume.

The cost of octane increases because of the reforming cost and/or the purchase of expensive high octane components. Therefore, as the volume of low octane naphtha increases, the cost of meeting the gasoline octane specification also increases. Octane cost and the price of light naphtha are inversely proportional. The chart below shows that the relative price of natural gasoline has trended downward as the cost of octane has trended higher.



TIER 3 GASOLINE: A NEW CHALLENGE

Additional challenges will present themselves when the EPA's Tier 3 rule comes into effect in 2017. Although previous Tier 2 regulations required major investments to reduce sulfur in gasoline, most refiners ignored light naphtha, since it contributed much less sulfur than other blendstocks. When Tier 3 sulfur limitations of 10 ppm begin in 2017, light naphtha will no longer easily fit in the blend pool, unless sulfur removal investments are made.

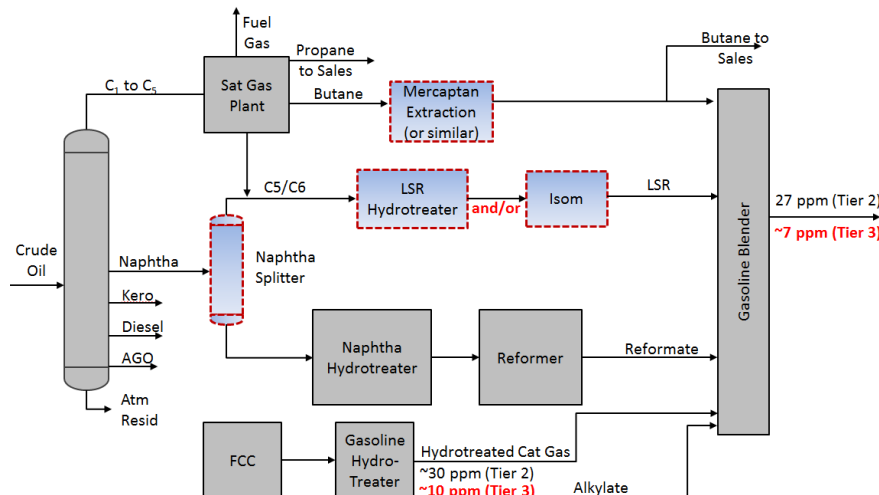
REFINERS' RESPONSES

Depending on the sulfur content of the crude oil feed to refineries, the sulfur content in light naphtha is typically 30 to 100 ppm. Therefore, many refineries will require new equipment to remove sulfur in previously untreated streams. Fortunately, for some, the investments made during preparation of the Tier 2 regulations to reach 30 ppm sulfur levels may also be adequate to reach 10 ppm sulfur levels with only operational adjustments. Some refineries may only need a new mercaptan removal unit for some liquefied petroleum gasoline (LPG) streams that, as of today, still may contain a prohibitive quantity of sulfur to meet 10 ppm levels. Sulfur, in the form of a lighter boiling mercaptan compound, is easier to remove with a mercaptan extraction unit versus a high boiling point sulfur-containing thiophene molecule that requires hydrotreating. The typical breakpoint between low-cost mercaptan extraction and more intensive hydrotreating is at the 5 to 6 carbon level. Therefore, some refineries will require more rigorous changes to remove sulfur from light gasoline components. Finally, some refineries may benefit from a modified fractionation scheme to segregate these streams into the appropriate sulfur removal unit.

The selection of new equipment to meet Tier 3 regulations will be dependent largely on the refinery's feedstock quality and its existing configuration. Every gasoline blend stream must be evaluated for its contribution to the sulfur pool. Even alkylate, which is usually considered to be an ideal blendstock, can contain as much as 25 ppm sulfur.

Since the high cost of octane is expected to continue, an isom unit that increases the octane of LSR may be an attractive investment. An investment in a naphtha splitter may increase the economic return for the refinery by allowing increased heavy naphtha to the reformer. In turn, this may benefit both the quality and volume of high octane reformat. For refineries with lower sulfur crude slates or limited budgets, a mercaptan extraction unit may allow a lower cost investment in place of a hydrotreater. The figure on the following page shows the possible changes to meet a refinery-gate gasoline specification of 7 ppm total sulfur.

POSSIBLE NEW REFINERY INVESTMENTS FOR TIER 3 COMPLIANCE



Meeting Tier 3 specifications will add costs that may include the loss of octane from higher severity hydrotreating of catalytic gasoline. It is well known that gasoline produced from Fluid Catalytic Crackers (FCC) has olefinic compounds (unsaturated) that lose octane when hydrotreated (saturated). One catalyst vendor concluded that the drop in gasoline octane across gasoline hydrotreaters (GHT) operated at moderate severity is approximately 0.8 numbers.¹ Since FCC gasoline often contributes as much as 50% of a complex refinery's gasoline pool, most refineries will be increasing the severity of these units to achieve a sulfur content of GHT product at 10 ppm or less, as shown in the figure above.

Expectations vary as to the extent of new octane losses at higher severities. Most refiners have conducted test runs at higher severity GHT operation and have internal predictions of these new octane losses. An informal survey of refiners and technology providers reveals that expectations are that octane losses will increase by 0.2 to 0.5 numbers when refiners increase severity of gasoline hydrotreaters. With this step change down in the refinery's octane pool, other changes will be necessary to maintain the gasoline pool octane. Light naphtha will be less valuable due to its relatively low octane.

Assuming the refiner's goal is to maintain its gasoline pool octane, its possible responses to this new drop in octane could be:

1. Add octane enhancing FCC catalyst additives (although this may already be in place).
2. Sell light naphtha and make less finished gasoline.

¹ Grace Catalysts Technologies Catalogram – 0.8 numbers is measured by "R+M/2," which refers to the average of research and motor octane numbers from laboratory analyses.

3. Sell more low octane gasoline and less high octane (premium) gasoline.
4. Buy or make more costly high octane components, like reformat and alkylate.
5. Build a naphtha splitter and optimize existing reformer feed to increase pool octane.
6. Install LSR sulfur removal and an isom unit.

Although refiners will likely choose an optimal mix of these options for flexibility, only the last one accomplishes both goals of reducing sulfur and increasing octane.

CONCLUSIONS

Although light naphtha has been a useful gasoline blending component for many years, expanding available volumes, quality issues, new environmental regulations, and limited alternate markets are presenting new challenges to refiners. The Tier 3 regulations will be especially difficult to meet for many refiners absent new investments with attendant additional operating costs. This will drive up the value of octane and drive down the value of light naphtha for many refiners. For example, refiners and blenders that rely on purchases of light naphtha and other components to blend gasoline with a maximum of 30 ppm sulfur will be severely impacted when the limit drops to 10 ppm sulfur. Price discounts on sales of traditional blendstocks, such as FCC gasoline, natural gasoline, and even alkylate, will be much deeper if the sulfur content is 15 ppm or higher. Because light naphtha and natural gasoline are expected to continue to be in surplus, if there is no ready means of sulfur removal, these materials can be expected to be severely discounted to clear them into alternative markets, such as petrochemical feedstock, heavy crude oil diluent, or exports.